Comparative study of pyrolytic carbon, zirconia-toughened alumina, and cobalt-alloy against cartilage: in vitro wear test with live tissue

Amandine Impergre [1)*], Layth Ben Trad[2)], Nathalie Bernoud-Hubac[2)], Ana-Maria Sfarghiu[2)], Markus A. Wimmer[1)]

[1)]Laboratory of Tribology, Orthopedic Department, Rush University Medical Center, USA
[2)] Univ Lyon, INSA-Lyon, CNRS UMR5259, LaMCoS, F-69621, France
*Corresponding author: Amandine_Impergre@rush.edu

Interposition arthroplasty is a new concept to treat the osteoarthritic shoulder joint to avoid total joint replacement. Pyrolytic carbon (PyC) has been chosen as an interposition ball for its excellent properties. This study aims to determine the tribological properties of PyC when articulated against cartilage. Cartilage viability analysis and biochemical markers suggest that PyC may induce less cartilage damage than cobalt alloy. Compared to alumina ceramics, no significant difference was observed. However, the PyC surface tended to adsorb more phospholipids than the other two biomaterials during rubbing, potentially improving lubrication.
Keywords: Pyrolytic carbon, cartilage, hemiarthroplasty

1. Introduction

Pyrolytic carbon (PyC) is used for partial shoulder replacement ("interposition arthroplasty") [1]. PyC has good biocompatibility, excellent fatigue properties, and wear resistance. Designed as a ball without anchoring to the bone, PyC is less invasive than many other arthroplasty solutions. This research aims to evaluate the damage of cartilage after articulation against PyC when compared with two other hemiarthroplasty materials: alumina ceramic (ZTA) and cobalt-alloy (CoCr).

2. Methods

Tribological tests of biomaterials articulating against bovine cartilage explants were performed for 5 days (Fig. 1). The lubricant was based on cell culture medium containing lubricating proteins of synovial fluid: phospholipid vesicles filled with hyaluronic acid. Cartilage damage was assessed using two viability tests (fluorescent marker and mitochondrial activity) and by quantification of biochemical markers released in the lubricant (sulfated glycosaminoglycans, sGAG). Phospholipids (PLT) that adsorbed on biomaterials were quantified by HPLC to correlate the surface state of the biomaterials with cartilage degradation.

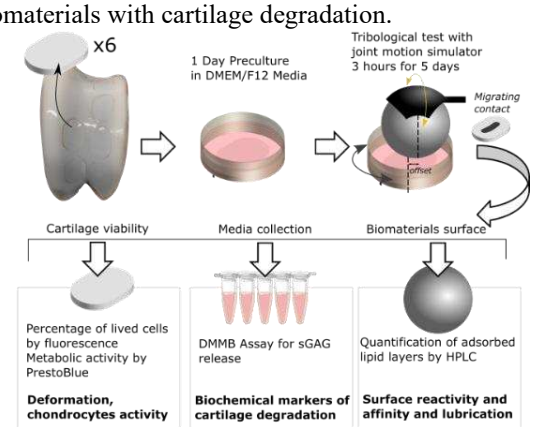

Fig. 1 Overview of the experimental design for the tribological evaluation of biomaterials articulating against cartilage.

2.1. Results

Both fluorescent cross sections and mitochondrial activity of cell cartilage of the half explant indicated that the CoCr (52±5%) induced the lowest viability, but similar percentage between ZTA (65±5%) and PyC (66±11%) (N=6, p=0.28). The release of sGAG in the collected media was lowest for PyC (0.21%), followed by ZTA (0.26%) and CoCr (0.29%) without any statistical significance (N=5, p=0.17) (Table 1). On average, although not significant, PyC showed the highest amount of PLT after testing (N=4, p=0.38). Only PyC appears to experience an increase of PLT at the surface due to rubbing (Fig. 2).

Table 1. Cumulative sGAG release as a percentage of cartilage explant wet weight into the media after articulating against biomaterials at day 0 (preculture) and testing days (1-5).

		CoCr	ZTA	PyC
sGAG release (% of cartilage wet weight)	*Day 0*	0.05%	0.05%	0.04%
	Day 1-2	0.08%	0.08%	0.05%
	Day 3-4	0.07%	0.08%	0.05%
	Day 5	0.08%	0.06%	0.07%
	Cumulative percentage	**0.29**	**0.26**	**0.21**

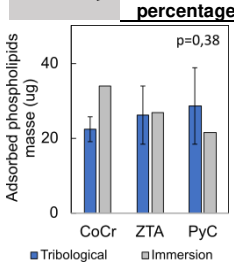

Fig. 2 Concentration of phospholipids adsorbed on biomaterials after tribological test against cartilage (blue) and immersion test (gray).

3. Discussion

Initial results suggest that CoCr causes the highest loss of viable cells, and that no differences are observed between PyC and ZTA. Similarly, the release of sGAG into the medium, characteristic for the early destruction of the cartilage matrix, suggests that it is less severe with PyC. Surface analysis of the biomaterials indicates that PyC induces a stronger adsorption of PLT by friction than other materials. PLT have been discussed to play a role in the friction between cartilage and biomaterials. Further testing is underway to confirm the trends observed in this study.

4. Acknowledgements

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5. References

[1] Garret. J. *et al.. J. Shoulder Elb. Surg.* **26**. (2017)